AD NUMBER
ADB344261
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution: Further dissemination only as directed by US Army Corps of Engineers, Sacramento District, 1325 J Street, Room 1480, Sacramento, CA 95814, MAR 1993, or higher DoD authority.**
AUTHORITY
COE/CA/SD ltr dtd 22 Oct 2008

Dupl

OFFICE REPORT

SACRAMENTO RIVER FLOOD CONTROL PROJECT
COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

US Army Corps of Engineers
Sacramento District

MARCH 1993

DEFENSE TECHNICAL INFORMATION CENTER

Information for the Defense Community

DTIC® has determined on Month 11 Day 03 Year 2008 *that this Technical Document has the Distribution Statement checked below. The current distribution for this document can be found in the DTIC® Technical Report Database.*

☐ **DISTRIBUTION STATEMENT A.** Approved for public release; distribution is unlimited.

☐ **© COPYRIGHTED.** U.S. Government or Federal Rights License. All other rights and uses except those permitted by copyright law are reserved by the copyright owner.

☐ **DISTRIBUTION STATEMENT B.** Distribution authorized to U.S. Government agencies only. Other requests for this document shall be referred to controlling office.

☐ **DISTRIBUTION STATEMENT C.** Distribution authorized to U.S. Government Agencies and their contractors. Other requests for this document shall be referred to controlling office.

☐ **DISTRIBUTION STATEMENT D.** Distribution authorized to the Department of Defense and U.S. DoD contractors only. Other requests shall be referred to controlling office.

☐ **DISTRIBUTION STATEMENT E.** Distribution authorized to DoD Components only. Other requests shall be referred to controlling office.

☒ **DISTRIBUTION STATEMENT F.** Further dissemination only as directed by controlling office or higher DoD authority.

Distribution Statement F is also used when a document does not contain a distribution statement and no distribution statement can be determined.

☐ **DISTRIBUTION STATEMENT X.** Distribution authorized to U.S. Government Agencies and private individuals or enterprises eligible to obtain export-controlled technical data in accordance with DoDD 5230.25.

OFFICE REPORT

SACRAMENTO RIVER FLOOD CONTROL PROJECT
COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

March 1993

EXECUTIVE SUMMARY

The Water Resources Development Act of 17 November 1986 authorized remedial construction necessary to restore the Sacramento River Flood Control Project levees along the Colusa Trough Drainage Canal and the Knights Landing Ridge Cut, subject to review and comment of the project work by the Secretary of the Army and the submittal of report findings to Congress. The Act stated that if the Secretary did not comment before the end of a 3-year period beginning on the date of the Act, the project work would be deemed to have been approved by the Secretary.

Construction General funds were appropriated in FY 90 under the Sacramento River Flood Control Project to initiate advanced engineering and design studies for the project levees within the study area. Additional funds were made available in FY 91 and FY 92 to determine the extent and scope of reconstruction work required to restore the levees to the congressionally authorized and approved design levels.

The study area includes about 13 miles of project levees on the Knights Landing Ridge Cut and about 36 miles of project levee on Colusa Trough Drainage Canal. Engineering and geotechnical evaluations indicate about 11 miles of levees require remedial construction to correct for stability and seepage problems inherent in the design and construction of the original project. Although there is always the question of adequate maintenance by the local agencies, it is concluded that the stability and seepage problems are the result of internal soil conditions (within the levee embankment and subsurface foundation) and not inadequate maintenance.

8.5 miles of the reconstruction work (located on the Colusa Trough Drainage Canal levee and the west levee of the Knights Landing Ridge Cut; see Figure 7) is not economically justified incrementally. The remainder of the work, 2.5 miles along the east levee of Knights Landing Ridge Cut, appears economically feasible when combined with reconstruction work proposed in the Mid-Valley Area Initial Appraisal Report (IAR) for that flood hazard area encompassing the community of Knights Landing. The first cost of the 2.5 miles of levee reconstruction on Knights Landing Ridge Cut is estimated to be about $2 million.

In addition to the above, there are localized depressed areas of the levee crown that do not have the minimum congressionally approved 3 feet of freeboard above the design water surface. The depressed areas of the levee crown are outside the limits of the remedial reconstruction work cited above and are generally located at railroad and road crossings. It is proposed that the local entities responsible for levee maintenance in these areas be required to install flood barriers or permanently fill such locations under existing maintenance and operation agreements to insure that the design flood stages can be safely conveyed within the project levees. This work is also within the financial capabilities of the local sponsor, The Reclamation Board.

The potentially feasible work (2.5 miles of levee reconstruction along the east levee of the Knights Landing Ridge Cut) will be considered in conjunction with the Mid-Valley Area levee reconstruction plan. The purpose of this office report is to present findings regarding work performed under Colusa Trough remedial construction authority. This office report includes a summary of geotechnical analysis, required levee reconstruction work, design, costs, and economic evaluation.

Considering Colusa Drain/Knights Landing Ridge Cut work in conjunction with the Mid-Valley Area is in accord with the recommendations presented in the Sacramento River Flood Control System Evaluation, Mid-Valley Area IAR. The east levee of the Knights Landing Ridge Cut in that report was assumed to provide the congressionally approved design level of flood protection, but it was recognized that additional detailed geotechnical studies were being done under the subject investigation. The construction of all work proposed around an independent flood hazard area as one unit will insure that the design level of flood protection for that area, including the community of Knights Landing, would be met at one point in time. Geotechnical and design information developed under the Colusa Trough authority will be incorporated into the Mid-Valley Area design memorandum. In addition, this will minimize engineering and institutional efforts since only one Project Cooperation Agreement (PCA), one set of plans and specifications, and one construction contract would be required for the Knights Landing area.

Other areas shown to be incrementally unjustified will be addressed as part of the Total Systems Costs and Benefits Evaluation pursuant to instructions regarding WRDA-92 and FY-93 work allowance instructions, and as elements within Phase IV, Lower Sacramento, or Phase V, Upper Sacramento, of the Sacramento River Flood Control System Evaluation.

Funds programmed for Colusa Trough after FY 92 are not required. Engineering and design costs expended in the evaluation of the east levee of the Knights Landing Ridge Cut will be transferred to the Mid-Valley Area design effort and would be cost shared by the local sponsor. Additional funds would need to be programmed in subsequent years for the Mid-Valley Area engineering and design effort.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

a) Study Authority – The levees of the Colusa Trough Drainage Canal and the Knights Landing Ridge Cut have had significant problems over the years. Their integrity has been maintained by local entities and supplemented by State and Federal aid, Public Laws 84–99 and 93–288, when applicable. A reconnaissance report was prepared in July 1981 to support the repair of potential project deficiencies. Resolution of this request was never finalized. With the passage of the Water Resources Development Act of 1986, repair of these levees was authorized in Section 830 subject to the provisions of Section 903(a). The authorization reads:

> *Subject to Section 903(a) of this Act, the project for flood protection along the Sacramento River and its tributaries, California, authorized by the Flood Control Act of 1917, is modified to authorize and direct the Secretary to accomplish remedial construction necessary to restore the project flood control levees along the Colusa Trough Drainage Canal and the Knights Landing Ridge Cut, in accordance with such report, at a total cost of $11,000,000, with an estimated first Federal cost of $8,250,000 and an estimated first non-Federal cost of $2,750,000.*

Section 903(a) required that, prior to commencing construction, the Secretary of the Army review and comment on the project and report to Congress. If such comment is not made before the end of the 3–year period beginning on the date of enactment of the Water Resources Development Act, the project will be considered approved by the Secretary of the Army.

b) Study Purpose and Scope – This study was conducted to evaluate the integrity of the existing levees of the Colusa Trough Drainage Canal and Knights Landing Ridge Cut, to determine whether the levees function as designed; to determine whether the levees have the minimum congressionally approved 3 feet of freeboard above the design water surface; and, if levee reconstruction is needed, to determine the economic justification for proceeding with construction. The existing levee embankments of the Colusa Trough Drainage Canal and Knights Landing Ridge Cut were constructed based on (1) a design water surface profile, (2) a discharge associated with the design water surface profile, and (3) a minimum freeboard requirement above the design water surface profile. In general, the study objective was to develop reconstruction plans to insure that the project levees could safely pass the design flood stages.

c) Other Studies and Reports – Detailed explorations, soil testing, and analyses of the levees and foundations within the project area are described in the following reports:

1) "Basis For Design, Levee Construction, Back Levee, RD 108, Sycamore Slough to SPRR Bridge, Sacramento River Flood Control Project," Corps of Engineers, September 1955.

2) "Design Memorandum No. 2, Sacramento River Flood Control Project, California, Back Levees of Reclamation District No. 108, Levee Construction General Design, " Corps of Engineers, August 1957.

3) "Design Memorandum No. 3, Sacramento River Flood Control Project, California, Back Levees of Reclamation District 108, Levee Construction General Design," Corps of Engineers, August 1957.

4) "Colusa Basin Drainage Canal Levee, Engineering Study," Converse Ward Davis Dixon Inc., March 1981.

5) "Office Report, Sacramento River Flood Control Project, California, Engineering and Economic Evaluation, Colusa Basin Drain and Knights Landing Ridge Cut, Units 127 and 132, Colusa and Yolo Counties, California," Corps of Engineers, April 1986.

6) "Decision Document, Sacramento River Flood Control Project, California, Engineering and Economic Evaluation, Colusa Basin Drain and Knights Landing Ridge Cut, Units 132 and 127, Colusa and Yolo Counties," Corps of Engineers, May 1988.

7) "Geotechnical Assessment of Levees in the Mid-Valley Area, Sacramento River Flood Control System Evaluation," Corps of Engineers, December 1989.

8) "Plan of Action, Sacramento River Flood Control Project, Colusa Basin Drain and Knights Landing Ridge Cut," Corps of Engineers, February 1990.

9) "Colusa Basin Appraisal," State of California, The Resources Agency, Department of Water Resources, May 1990.

10) "Sacramento River Flood Control System Evaluation, Mid-Valley Area, Initial Appraisal Report," Corps of Engineers, December 1991

11) "Cultural Resources Inventory for the Colusa Basin/Knights Landing Ridge Cut Levees Project, Colusa and Yolo Counties, California," PAR Environmental Services, April 1992.

12) "Baseline Resources Inventory, Colusa Basin and Knights Landing Ridge Cut," Beak Consultants Incorporated, May 1992.

II. STUDY AREA DESCRIPTION

a) Study Location – The Colusa Basin is an area northwest of the city of Sacramento. The basin extends from the Sacramento River on the east to the crest of the foothills on the west, with Stony Creek and Cache Creek the approximate northern and southern boundaries, respectively. (See Figure 1.) The basin has a drainage area of approximately 1,700 square miles, a length of about 70 miles, and a maximum width of about 25 miles. The lands of the basin are used primarily for agriculture, with about 100,000 acres devoted to rice production. Waterfowl hunting at private clubs and on public preserves is also a major industry in the northern part of the basin. The population of Colusa Basin is mostly contained within the cities and towns of Willows, Maxwell, Colusa, Williams, Arbuckle, Dunnigan, and Knights Landing; smaller communities are in the outlying areas. The population of Colusa Basin is increasing at a rate of about 1.4 percent annually. The January 1987 population estimate was 21,800.

b) **Area Description** – The development of Colusa Basin into a productive agricultural area has depended upon the progressive reclamation of the area to prevent flooding, improve drainage, and provide irrigation. Individuals, local districts, the State, and Federal agencies through the years have constructed various flood control works necessary to the farming of the fertile areas located within the basin. Local reclamation districts were the first agencies to develop the area for agriculture. Investigations and proposals by State and Federal Governments in the early 1900's concerning flood protection of the Sacramento Valley greatly influenced the subsequent developments within the basin.

c) **History of Study Area Project Levees** – The levee of Reclamation Districts 108 and 787 and Maintenance Area 12 extends from the vicinity of Colusa along the eastern side of the Colusa Trough Drainage Canal through Knights Landing. (See Figure 2.) This levee was originally constructed to protect lands to the east of the Colusa Trough Drainage Canal from flood runoff originating from the western foothills. Local interests constructed the Colusa Trough Drainage Canal, which flows south from its junction with Willow Creek above the town of Colusa and then along the alignments of the levee of Reclamation Districts 108 and 787. Excavated material was used to build the levee of this channel, and in some reaches excavation was necessary to provide a continuous drainage channel of the desired capacity. The levee was originally constructed by local interests between 1911 and 1918 using a clamshell dredge. The levee was gradually improved and final modifications were completed in 1958 to meet the design specifications for the Sacramento River Flood Control Project and to provide flood protection for lands to the east against flows up to 20,000 cubic feet per second (cfs). However, floodflows that exceed the Trough's in-channel capacity of 1,500 cfs have caused and will continue to cause extensive flooding of lands west of the levee.

During low stages on the river, flows from the Colusa Trough Drainage Canal are discharged through a concrete structure, the Knights Landing Outfall Gates, into the Sacramento River. When the stage of the Sacramento River is high, the gates are closed, and flows from Colusa Trough Drainage Canal are conveyed through Knights Landing Ridge Cut into the Yolo Bypass. The Knights Landing Ridge Cut, which has a bottom width of 400 feet, was constructed by excavating two parallel channels and using the excavated material to construct two levees on the outside of each channel. The leveed cut was designed to convey 20,000 cfs. The two combined excavated channels act as low flow outlet channels for the Colusa Trough Drainage Canal.

III. PROBLEMS

a) **General** – The levees in the Colusa Trough Drainage Canal and Knights Landing Ridge Cut have experienced subsidence, slippage, and partial collapse over the years. Historic records, dating to 1915, indicate failures have occurred on both sides of the levees and repairs have been made throughout their existence. Records dating to 1959 show subsidence and slumping of many short levee reaches (200 feet or less). In some cases, levees were repaired by excavating and recompacting as much as one-half

of the levee cross section. These failures have been extensive and threaten the integrity of the levee system.

The cost of such work has frequently exceeded the financial capabilities of the local districts to repair the levees, and the assistance of the Corps of Engineers has been provided under Public Law 84-99. Previous Public Law 84-99 work is shown in Table 1. However, continuous intensive maintenance programs and prompt and effective emergency actions have been necessary to prevent levee breaches and flooding of the protected areas.

b) Levee **Embankment Problems** - Corps documents dating to 1951 have described levee deformation, slippage, and partial collapse. Levee damage has resulted from the following: (1) loss of strength and cracking of the near surface soils, (2) precipitation and flood stage water forces, (3) a weak layer of foundation clay and/or organic material, and (4) over steepened levee geometry. Many of the failures have been on the landside of the levees. Slope failures are often shallow surficial slides involving the upper 5 feet or so of material and do not extend into the crown. Deeper slides manifest themselves as longitudinal cracks extending into the crown. The landside or waterside slope gradually deforms several inches to several feet per day until equilibrium of the sliding mass is reached. The typical result is a 4- to 7-foot vertical escarpment in the crown which may extend for 200 to 1,000 feet. Material in the levee foundation moves laterally along a weak layer of soft clay and organic debris (tule reeds, grasses, carbon chunks, and decayed matter) and comes to rest 20 to 30 feet beyond the levee toe. Deformation problems have been described as several feet of subsidence in the crown accompanied by bulging of the sides between the toe and crown.

During 8 of the past 34 years (1958, 1959, 1969, 1974, 1975, 1980, 1983, and 1986), damages to the levees of the Colusa Trough Drainage Canal, RD 108/787, warranted Public Law 84-99 assistance. Repairs in 1959 consisted of reconstructing small portions of the levees at various locations. In 1974, 1980, and 1984 (1983 damages), repairs consisted of reconstructing approximately 5,200 feet of the levee. During the same 34-year period, Knights Landing Ridge Cut levees required assistance under Public Law 84-99 in 4 years (1956, 1963, 1975, and 1986). In 1963, repairs consisted of reconstructing approximately 1,600 feet of levees on both sides of the channel. In addition, in 1983 non-Federal interests received assistance from the Federal Emergency Management Agency for damages not subject to Public Law 84-99 assistance.

Repairs have included removal and compaction of the failed material to flatten slopes with the inclusion of a berm to counterbalance the rotational failure of the levee fill. A total of 67 levee repair and reconstruction sites have been noted in Corps documents since 1956. In many other instances, non-Federal interests have repaired the levees when Federal aid was not available as levee failures occurred in years when no flood emergency was declared.

TABLE 1
KNIGHTS LANDING RIDGE CUT AND COLUSA TROUGH DRAINAGE CANAL PUBLIC LAW 84-99 WORK

Year	Reclamation District	Levee Mile	Length	Damage	Actual Cost ($)	Cost ($) Oct 91 Price Level
1956	KLRC	2.5	1,600	Slip, Subsidence	50,000	290,358
1963	KLRC	0.7, 0.85	1,850	Slip, Subsidence	60,000	300,344
1969	108 787	2.4	Combined 350	Slip	22,000	88,808
1974	108 787	0.0, 2.1-3.7 2.2, 4.2	Combined 2,250	Structural Failure	Combined 69,000	 191,380
1975	108 787	14.9, 15.4 1.98, 2.73	400 200	Landside Slip Slip	37,000 23,500	86,975 55,241
1980	108	0.15, 1.8, 2.25	3,150	Slip, Subsidence	304,000	466,470
1983	108	0.22-17.4	10,300	Slips	509,000	618,557
1986	KLRC	2.25, 2.4, 2.6	900	Slip, Subsidence	60,000	70,110
				TOTAL COST	1,134,500	2,168,243

KLRC = Knights Landing Ridge Cut

c) **Flood Problems** - Under existing conditions, land on the west side of the Colusa Trough Drainage Canal levee is flooded during peak floodflows. This situation has existed since the early part of the century when the levee was first constructed by non-Federal interests. During an event such as the 100-year (1983) flood, the peak flood stage would be reduced about 3 feet by a levee breach. Peak stages are of short duration when compared with periods of inundation generally experienced by the westside lands (peak stage periods generally last about 1 to 2 weeks on the average). The primary problem is that flow in the Yolo Bypass produces prolonged periods of backwater inundation in the Colusa Trough Drainage Canal. Flood records indicate that westside lands may be inundated for several months and that the inundation may extend into May.

If levees along the Colusa Trough Drainage Canal are breached, there will be a reduction in the extent of westside lands inundated. This reduction in flooded areas around the perimeter is not really significant. The duration of flooding of the westside lands would also change because of a levee break but is dependent on how floodwaters are removed from flooded areas east of the Colusa Trough and reintroduced into the system. There will be no change to westside flooding levels, assuming the Colusa Trough Drainage Canal levee provides the design level of protection.

Flood stages in the Colusa Trough Drainage Canal and Knights Landing Ridge Cut are a function of runoff upstream from the town of Colusa, local runoff, and backwater effects from the Yolo Bypass. Antecedent weather conditions prior to floods are characterized by extensive and frequent rainy periods. During these periods, rainfall which averages more than one-third of an inch per day occurs more than 50 percent of the time, with only short periods of clearing (less than 10 days) for periods up to 4 months. These wet weather conditions result in saturation of the levees and corresponding softening of the levee fill adjacent to cracks or fissure surfaces. As noted in the geotechnical analyses (Section IV-c), the fissure orientation, intrusion of water, and associated softening of the fissure surfaces may cause slope failures.

Levee damages usually consist of partial slope failures or subsidence, with the majority of damages occurring on the landward side of the levee. Repair of these damages often requires excavation and reconstruction of the entire levee cross section. During reconstruction it has been observed that the levees contain fissured clay and that the underlying foundation contains organic clays with local layers of vegetation that has not decomposed.

IV. ENGINEERING AND DESIGN

a) **General** - This study was conducted to evaluate the integrity of the existing project levees of the Colusa Trough Drainage Canal and Knights Landing Ridge Cut; to determine whether the levees function as designed; to determine whether the levees have the minimum congressionally approved 3 feet of freeboard above the design water surface; and, if levee reconstruction is needed, to determine the economic justification for proceeding with reconstruction. If levee reconstruction is needed, reconstruction plans would be developed to insure that the project levees can safely pass the design flood stages.

b) **Levee Crown and Design Water Surface Profiles** - Levee crown surveys were completed on the Colusa Trough Drainage Canal and the Knights Landing Ridge Cut in September and December of

1990, respectively. Levee crown elevations are referenced to mean sea level datum. Levee crown stationing (and the design water surface profile) was based on "Levee and Channel Profiles," Corps of Engineers, March 1957, as revised.

Survey points were taken on the centerline of the levee crown about every 1,000 feet and at breaks in the levee crown profile. Additional survey points were taken at railroad crossings, road crossings, and at other significant physical features. Levee crown profiles developed from the survey data are shown in Figures 3 through 6.

The profile plots indicate the non-uniformity in the levee crown surfaces in the study area. In addition, the plots indicate that some road crossings cut through the levee embankments at elevations 1 to 3 feet below the adjacent levee crown elevations.

Design water surface profiles were developed for Colusa Trough Drainage Canal and Knights Landing Ridge Cut as part of the Sacramento River Flood Control Project, as indicated by "Levees and Channel Profiles," Corps of Engineers, March 1957. Design water surface elevations were based on a specified design discharge (no recurrence interval or frequency was attached to that design discharge) and adopted concurrent conditions at the confluences of study area streams and bypasses.

Project flood plains were originally adopted by the March 1917 Flood Control Act as taken from House Document No. 81, 1st Session, dated 1910. In 1923 , House Document No. 81 was modified to show changes to the recommended project because of significant cost increases, local desires, and to incorporate work which had already been done by locals in the interim. Revised values for project design flows and flood plains were established and included in the report "Flood Control in the Sacramento and San Joaquin Basins," printed as Senate Document No. 23, 69th congress, 1st Session, 1926. This is the basic document authorizing the 1928 revision of the project. Since 1928, project design flows and water surface profiles have been reevaluated and modified based on available hydrologic information and more detailed hydraulic studies, and as various segments of the project were constructed. These revisions have been agreed to by The Reclamation Board, State of California, and the Corps of Engineers and published as "Levee and Channel Profiles, Sacramento River Flood Control Project," 15 March 1957.

The agreed-to 1957 design water surface profiles are shown on Figures 3 through 6 and can be compared to the levee crown profile plots.

Three feet is the minimum freeboard on the Colusa Trough Drainage Canal and Knights Landing Ridge Cut project levees to meet design requirements for the flood control project levees and to provide for a uniform level of protection from overtopping. An inspection of the profile plots indicates that freeboard is inadequate on Knights Landing Ridge Cut at the Road 16 crossing and in the vicinity of channel mile 12, and on Colusa Trough Drainage Canal at the Road 99E crossing, in the vicinity of channel mile 4, between channel miles 12 and 14, at the County Line Road crossing, and in the vicinity of channel mile 17.

Although road crossings do not meet minimum design freeboard requirements, local levee maintaining agencies should have operational procedures for sandbagging or for installing flood gates at these locations during high flood stages. In addition, other localized depressed areas of the levee crown have

deficient freeboard ranging up to about a maximum of 1 foot. Because these areas are very localized, because the magnitude of the freeboard deficiency is small, and because the reasons for the deficiencies cannot be positively associated with design or construction deficiencies, the depressed areas should be raised under existing maintenance and operation agreements.

c) **Geotechnical Analyses** - Geotechnical analyses were conducted on the Colusa Trough Drainage Canal and Knights Landing Ridge Cut project levee embankments and levee foundations to evaluate levee stability and provide reconstruction designs for levees with inherent design and construction deficiencies. Reconstruction designs were selected on the basis of current explorations and testing and a review of previous investigations and information.

The current geotechnical investigation included a total of 88 borings drilled in June and July of 1990 for the purpose of determining the properties and characteristics of the levee embankment and foundation soils. A 6-inch diameter hollow-stem auger was used to drill to depths of 40 feet from the levee crown and 20 feet from the levee toe (generally two borings per site). Additional borings were drilled to investigate slumping. Standard penetration tests (SPT's) were conducted continuously from the surface to a depth of 20 feet and then at 5-foot intervals thereafter except in alternating borings where undisturbed and bulk samples were taken. In addition, in November 1990, a total of five exploration trenches were excavated in the levee embankment at selected sites within the project area for the purpose of evaluating levee crackage. Two trenches were excavated on the landside of the Knights Landing Ridge Cut, and 3 trenches were excavated along the Colusa Trough Drainage Canal levee at known levee problem areas. The purpose of the trenches was to trace the depth of the larger cracks and to view the zone of drying and cracking. The above information was supplemented with boring logs from previous investigations by the Corps of Engineers, other geotechnical firms, and with data from past levee repairs.

Levee embankment cross section surveys indicated levee slopes ranging from 1.5 horizontal to 1 vertical (1.5H:1V) to 4.0H:1V on the waterside and 2.0H:1V to 5.5H:1V on the landside. The crown width varies from 12 to 60 feet on the Knights Landing Ridge Cut and 18 to 80 feet on the Colusa Trough Drainage Canal. The predominant crown width is 25 feet for the Colusa Trough Drainage Canal and 15 feet for the Knights Landing Ridge Cut. The typical levee height above the natural ground surface is 15 feet for the levee reaches. However, the levee in some reaches is as high as 20 feet. A landside ditch 10 feet deep and 30 feet wide parallels the landside toe for much of the project.

The laboratory testing program indicated that the soil samples obtained from the levee embankments and foundations were primarily clays. There were 15 samples selected to represent the embankment and foundation and 8 samples chosen as representative of the clay-organic layer. Testing indicated that a well defined peak strength was not reached by 10 of the 23 samples tested. The descriptions of past failures indicated a gradual remolding and loss of strength of material prior to failure; however, creep as a mode of failure was not established.

Soil-lime testing consisted of using material from three sites that were selected as representative of the levee embankment and foundation soils. Clay-organic material was not tested because acid from decaying organic matter inhibits the interaction of lime with clay. Soils with an organic content greater

than 20 percent are considered nonreactive with lime. Soils tested had an organic content of about 6 percent. Laboratory test results indicated that cracking and shallow sloughing may be prevented with the addition of 4 percent lime to the clay and that the soils of the project levees are conducive to lime treatment. Potential reconstruction work on the Colusa Trough Drainage Canal, about 8,000 lineal feet of levee between roads 99E and 98A, would use a lime treatment to prevent cracking of the near-surface levee material. Lime at a rate of 4 percent by weight would be mixed in place to a depth of 2 to 3 feet. Any organic matter encountered would be removed.

The slope stability analyses determined that the critical condition for landside slope stability occurs at the design flood stage with uplift pressure transmitted through the shallow foundation organic layer. Waterside slope stability is most critical at low-flow conditions at locations where the freeboard is greatest.

All levee reaches have shallow stability problems regardless of slope geometry or flood stage. The expansion characteristics of the clay materials and the long periods of seasonal wetting and drying result in progressive loss of strength. The shallow slides are confined to the upper few feet of material and typically daylight at the levee toe, channel bank, or ditch bank. Deeper slides fall along the plane of the clay-organic layer. In general, the more stable reaches have (1) slopes flatter than 3H:1V, (2) a landside height less than 15 feet, (3) no channel or ditch bank within 50 feet of the levee toe, and (4) no underlying clay-organic layer. The analyses did not consider the dense growth of large trees along the waterside bank of the Colusa Trough Drainage Canal. Based on the height of these trees, the root system is estimated to extend to a depth of 30 feet into the foundation soil. The roots could increase the resistive force of the available shear strength along the failure plane.

Based on the results of the geotechnical evaluation, engineering judgement, and past performance, the following reconstruction plans are recommended to insure that the project levees can safely convey the design flood stages:

Colusa Trough Drainage Canal *

15,500 lineal feet landside irrigation ditch relocation and intermittent toe berm construction (with 8,000 lineal feet of lime treatment) up to Road 98A. Upstream of Road 98A plan consists of 29,000 lineal feet of landside irrigation ditch relocation and toe berm construction.

Knights Landing Ridge Cut *

West Levee - Reconstruction plan consists of 500 lineal feet of landside irrigation ditch relocation.

East Levee - Reconstruction plan consists of 13,500 lineal feet of landside irrigation ditch relocation and 11,500 lineal feet of toe berm construction.

* See Figure 7

d) **Designs** - Designs for reconstruction of levees along the Colusa Trough Drainage Canal and Knights Landing Ridge Cut were based on results from the current geotechnical analyses and a review of test results and previous designs presented in "Colusa Basin Drainage Canal, Engineering Study" (reference 4).

The test results presented in the consultant's report indicated that the fissured structure of the uppermost foundation material significantly affects the strength of the material. The stability analysis showed that failure surfaces passing through this fissured layer could cause the Colusa Trough Drainage Canal levee to fail. Thus, the presence of this fissured layer suggests that the levee should be reshaped. The report indicates the following three solutions (reconstruction designs) based on their testing results:

1) Reconstruction design 1 - The levee would be excavated to foundation level and then reconstructed. The results of a number of soils tests indicated that excavating the levee to the foundation material and recompacting the soil such that the fissured structure is eliminated would be a viable solution. Previous repairs of the levee used this method with the provision that highly organic layers of materials be removed and inspections made to insure that such layers were not present when the levee was replaced. Most of the repaired sections have been performing satisfactorily; however, a previously repaired section in RD 108 reportedly failed. The failure could be due to inadequate depth of excavation or width of the key (remolding of fissured clay).

2) Reconstruction design 2 - The driving force would be reduced by removing material from the top of the slope and placing it near the toe. This measure involves excavating a portion of the landside slope and decreasing the crest width and placing and compacting the excess material into a berm near the toe of the slope. The geometric configuration would be a 16-foot crown width with a 2H:1V landside slope and a 27-foot wide berm at the landside toe. The waterside slope would remain unchanged. In this method, the final levee would have a split section, and the factor of safety would be higher due to an improved geometric configuration. This plan would not remove the fissured structure or organic layers in the unexcavated portions of the levees.

3) Reconstruction design 3 - The basic designs of the first two alternatives would be used. This design consists of excavating the levee and the upper few feet of foundation soils and compacting the material into the split-level geometric configuration described in design 2. This method would give the highest factor of safety.

Based on analysis of the designs presented in the consultant's report, geotechnical analyses done for the current investigation, and basic engineering judgement, the following designs have been recommended:

a) Berms will be added to provide a differential of 15 feet between the levee crest and the top of berm to stabilize the levee slope from potential deep failures. The berm is to extend horizontally a minimum of 20 feet from the levee slope with a minimum thickness of 2 feet. (See Figure 10.) Ditches are to be relocated a minimum distance of 50 feet from the levee toe . (See Figure 11.)

b) The upper 2 to 3 feet of material from the levee crown to the toe will be treated with lime to prevent cracking and to stabilize the levee slopes from potential shallow slides and deformation. The treatment area will extend between roads 99E and 98A.

c) Landside ditches near the levee toe will be relocated a minimum distance of 50 feet from the levee toe to improve slope stability. (See Figure 9.)

e) **Hydraulics and Hydrology** – Within the study area, the Colusa Trough Drainage Canal is leveed only on the left bank for about 36 miles. The upstream limit of the levee is south of the city of Colusa and just south of Highway 20. The Knights Landing Ridge Cut is leveed on both the left and right banks for about 13 miles.

Floodflows accumulating upstream of the project levee on Colusa Trough Drainage Canal are conveyed downstream past Highway 20 and down the drain to the Knights Landing Ridge Cut. Additional local inflows are intercepted at various points along the drain. During low stages, flows do not enter the Knights Landing Ridge Cut but are discharged through the outfall gates into the Sacramento River just north of the community of Knights Landing. During high stages, the outfall gates are closed and floodflows are conveyed through the Knights Landing Ridge Cut into the Yolo Bypass.

The study area has a gaging station at Highway 20 (flow and stage) and at Knights Landing (stage only). The gage at Knights Landing is upstream of the entrance to the Knights Landing Ridge Cut and west of the outfall gates to the Sacramento River.

The Corps of Engineers modified the levee embankments of the Knights Landing Ridge Cut in 1952 and the Colusa Trough Drainage Canal in 1956 and 1958 to meet design criteria authorized for the Sacramento River Flood Control Project. The minimum design freeboard was specified as 3 feet. The approved design water surface profiles are shown on Figures 3 through 6. Since modification of the existing levees by the Corps, no breaching of the levee embankments has occurred to date, although areas of significant levee distress have been observed (see photo, front cover) during and after flood events.

A design overflow location exists immediately upstream of the entrance to the Knights Landing Ridge Cut on the right bank. Overflow is initiated at about the design water surface elevation at this location. If overflow occurs, excess flows would be conveyed around the project levee and downstream on the landward side of the west levee of the Knights Landing Ridge Cut.

During the 1986 flood event, overflow did not occur to the west of the Knights Landing Ridge Cut for an observed peak flood stage of 35.94 feet (msl datum) at Knights Landing (see 1986 high water mark profile of Figure 3). During the 1983 flood event, when the observed peak flood stage was 37.35 feet at this same location, overflow did occur and floodflows traveled southerly along the landward side of the west levee of the Knights Landing Ridge Cut.

The peak stage for the 1986 flood in the Yolo Bypass at the confluence with the Knights Landing Ridge Cut was about 34.0 feet. (See Figure 3.) The peak stage exceeded the design water surface by about 0.3 feet. Based on the following stage-frequency data, which was developed for Yolo Bypass at this location (Yolo Bypass at the confluence with Knights Landing Ridge Cut), the peak stage represented a recurrence interval of 50 to 55 years.

Recurrence interval (years)	50	40	30	20	10
Yolo Bypass stage (feet) **	33.7	33.1	32.7	32.0	30.4

** Yolo Bypass at the confluence with Knights Landing Ridge Cut

For the 1983 flood, the peak flow rate observed at Highway 20 was 15,700 cfs. According to the Department of Water Resources (State of California), the 1983 recorded flow did not include overbank flow. Total flow has been estimated as 22,400 cfs. Using the following discharge-frequency data supplied by Hydrology Section, the 1983 peak flow, 22,400 cfs, at this location corresponds to a recurrence interval of about 40 years. The peak flow rate for the 1986 flood was 11,600 cfs and corresponds to a recurrence interval of about 10 years.

Recurrence interval (years)	100	50	25	10
Peak flow (cfs) **	34500	26000	19000	11800

** Colusa Trough Drainage Canal at Highway 20

Since peak flood stages in the Knights Landing Ridge Cut and Colusa Trough Drainage Canal are influenced by the flood stages in Yolo Bypass (backwater condition), a one-dimensional unsteady flow model was developed for the study area. Water surface profiles were developed for various flow rates and downstream stage-boundary conditions. The maximum peak flood stages during the 1983 and 1986 floods were estimated to have recurrence intervals of 40 to 55 years based on the hydraulic modeling and hydrologic inputs.

f) **Reconstruction Costs** - Since previous studies have never identified an economically feasible project for the subject study area, costs in the current investigation were only developed to that extent necessary to determine whether the work was potentially feasible.

The geotechnical evaluations, limits of reconstruction, reconstruction designs, costs of levee modifications and drainage facilities, and costs of relocations were done to that detail necessary for incorporation into a design memorandum. This was done such that if the reconstruction was shown to be infeasible, the information would be available to local entities and would permit those entities to make decisions and implement the necessary work without significant additional engineering and design efforts.

The reconstruction costs were developed for three separate reconstruction plans, the west levee of the Knights Landing Ridge Cut, the east levee of the Knights Landing Ridge Cut, and the levee on the Colusa Trough Drainage Canal. Each of these plans was associated with a potential flood hazard area (see Figure 8 for the general location of the flood hazard areas) for economic purposes.

Reconstruction costs are shown for each plan in Tables 2, 3, and 4. A general description of each applicable plan is contained in the first footnote of each table. Costs for relocations, levee modifications and drainage facilities were done in sufficient detail for incorporation into a design memorandum. Costs for real estate were estimated based on work previously accomplished by Real Estate Division for the Mid-Valley Area cost estimates, which include similar land types for value purposes. This work was

TABLE 2
KNIGHTS LANDING RIDGE CUT (WEST LEVEE) [1]
CONSTRUCTION COSTS
RECONSTRUCTION PLAN

Item	First Cost
Lands and Damages	$50,000 [2]
Relocations	$33,000
Fish and Wildlife Facilities	$20,000 [2]
Levee Modifications and Drainage Facilities	$76,000
Cultural Resources Preservation	$5,000 [2]
Planning, Engineering, and Design	$190,000 [2] [3]
Construction Management	$10,000 [2]
TOTAL	$384,000

[1] Reconstruction plan consists of 500 lineal feet of landside irrigation ditch relocation.

[2] Estimated using amounts for similar work shown in the Sacramento River Flood Control System Evaluation – Initial Appraisal Report – Mid-Valley Area, December 1991.

[3] Includes costs expended during current investigation.

TABLE 3
KNIGHTS LANDING RIDGE CUT (EAST LEVEE)[1/]
CONSTRUCTION COSTS
RECONSTRUCTION PLAN

Item	First Cost
Lands and Damages	$400,000 [2/]
Relocations	$78,000
Fish and Wildlife Facilities	$200,000 [2/]
Levee Modifications and Drainage Facilities	$803,000
Cultural Resources Preservation	$20,000 [2/]
Planning, Engineering, and Design	$400,000 [2/] [3/]
Construction Management	$70,000 [2/]
TOTAL	$1,971,000

1/ Reconstruction plan consists of 13,500 lineal feet of landside irrigation ditch relocation and 11,500 lineal feet of toe berm construction.

2/ Estimated using amounts for similar work shown in the Sacramento River Flood Control System Evaluation – Initial Appraisal Report – Mid-Valley Area, December 1991.

3/ Includes costs expended during current investigation.

TABLE 4
COLUSA TROUGH DRAINAGE CANAL[1/]
CONSTRUCTION COSTS
RECONSTRUCTION PLAN

Item	First Cost
Lands and Damages	$700,000 [2/]
Relocations	$8,000
Fish and Wildlife Facilities	$400,000 [2/]
Levee Modifications and Drainage Facilities	$2,664,000
Cultural Resources Preservation	$40,000 [2/]
Planning, Engineering, and Design	$1,200,000 [2/ 3/]
Construction Management	$190,000 [2/]
TOTAL	$5,202,000

1/ Reconstruction plan consists of 15,500 lineal feet landside irrigation ditch relocation and intermittent toe berm construction (with 8,000 lineal feet of lime treatment) between Knights Landing and Road 98A. Upstream of Road 98A plan consists of 29,000 lineal feet of landside irrigation ditch relocation and toe berm construction.

2/ Estimated using amounts for similar work shown in the Sacramento River Flood Control System Evaluation – Initial Appraisal Report – Mid–Valley Area, December 1991.

3/ Includes costs expended during current investigation.

coordinated with District Real Estate Division, and a breakdown of cost for each plan is presented in Table 5. Other costs were also estimated using amounts for similar work shown in the Sacramento River Flood Control System Evaluation, Initial Appraisal Report, Mid-Valley Area, December 1991. Since, as indicated below in the Economic Justification, the reconstruction work was shown to be infeasible based on existing conditions and an incremental resource analysis, no further refinement of quantities and cost was considered necessary.

g) Economic Justification - Based on past performance and the geotechnical evaluation, the levee reconstruction shown in Figure 7 is necessary to insure that the design flood stages can be safely conveyed by the project levees. The geotechnical evaluation also indicated a high potential for levee failure at flood stages equal to or greater than the higher of the peak flood stages that occurred during the 1983 and 1986 floods.

Potential flooded areas (see Figure 8) were developed assuming various breach scenarios and different without project condition levels of flood protection. Without project damages were computed for the various scenarios in an effort to determine whether the levee reconstruction was incrementally justified at a reconnaissance level.

During high flood stages a levee break on the west side of the Knights Landing Ridge Cut (at the site where ditch relocation is the recommended repair, see Figure 7) would result in flooding to an area bounded by the Cache Creek and Yolo Bypass project levees. (See Figure 8.) The potential flooded area is predominantly agriculture with farmsteads. Even if the recommended levee repair is made at this time, higher levels of flood protection for this area are probably not possible. As indicated previously, floodwaters circumvented the upstream limit of the west levee of the Knights Landing Ridge Cut during the 1983 flood and caused flood damages to areas landward of that levee. In addition, during the 1983 flood the north levee of Cache Creek just downstream of the community of Yolo was sandbagged to prevent overflow of the levee. If overflow or levee breaching would occur at this location, floodwaters would be conveyed downstream into the same general area shown flooded in Figure 8 (the estimated design level of flood protection for Cache Creek in the vicinity of Yolo is probably between a 10- and 20-year recurrence interval). Based on the above, higher levels of flood protection could not be achieved for that flood hazard area west of the Knights Landing Ridge Cut by relocating the ditch adjacent to the landward toe of the west levee. Since higher levels of flood protection cannot be attributed to the recommended repair for the west levee of the Knights Landing Ridge Cut, this work is not economically justified on an incremental basis.

Although the reconstruction proposed for the west levee of the Knights Landing Ridge Cut cannot be justified, the local maintaining agency or the State should consider doing the necessary work. If economic justification were shown and if Federal participation were approved, the cost of relocating ditch facilities would have been a local responsibility under current cost sharing policies.

TABLE 5
Knights Landing Ridge Cut and Colusa Trough Drainage Canal
Summary of Permanent and Temporary Right-of-Way, Staging Areas, and Land Acquisition Costs

Reach Description of Work	Length of Work	Avg.Width of Perm.R/W	Perm.R/W Required (Acres)	Perm.R/W Costs ($3000/Acre)	Avg.Width Temp.R/W	Temp.R/W Required (Acres)	Temp.R/W[1] Costs ($1800/Acre)	Staging Areas (Acres)	Staging[2] Area Costs ($900/Acre)	# of Parcels	Parcel Acquisition Admin.Costs	Total Costs
KLRC WEST LEVEE												
*500 LF Ditch Relocation	500	76.0	0.9	$2,600	20.0	0.2	$400	1.0	$900	1	$40,000	$43,900
KLRC EAST LEVEE												
*11,500 LF Ditch Relocation and Berm Construction	11500	76.0	20.1	$60,200	20.0	5.3	$9,500	1.0	$900	6	$240,000	$310,600
*2,000 LF Ditch Relocation	2000	76.0	3.5	$10,500	20.0	0.9	$1,700	2.0	$1,800	2	$80,000	$94,000
COLUSA TROUGH DRAINAGE CANAL												
*15,500 LF Ditch Relocation and Berm Construction	15500	76.0	27.0	$81,100	20.0	7.1	$12,800	2.0	$1,800	2	$80,000	$175,700
*29,000 LF Ditch Relocation and Berm Construction	29000	76.0	50.6	$151,800	20.0	13.3	$24,000	2.0	$1,800	9	$360,000	$537,600

[1] Tempoary easements are for a 2-year period.

[2] Staging area easements are for a 1-year period.

For the Colusa Trough Drainage Canal, about 8.5 miles of levee reconstruction is proposed just upstream of the Knights Landing Ridge Cut. (See Figure 7.) Based on the geotechnical and hydraulic analyses, the most probable levee breach location is in the uppermost levee reach of the recommended repair. If a levee were to break at an upstream location, another break downstream on Colusa Trough Drainage Canal is not expected. The potential flooded area for the above condition is shown in Figure 8.

The potential flooded area is bounded by a local levee to the south, the Sacramento River levee to the east, and the Colusa Trough Drainage Canal levee on the west. The area is predominantly agriculture with scattered farmsteads. The economic evaluation indicated that the average annual without project damages for existing conditions, a 21-day duration of flooding, and a 50-year nondamaging level of flood protection is about $115,000. Even if all the foregoing damages could be eliminated by the proposed reconstruction, the potential benefits would only support about $1.4 million of repair work. As shown in Table 4, the cost of levee modifications is in excess of $2 million which would indicate that the work on Colusa Trough Drainage Canal is economically infeasible on an incremental basis.

In addition to the above, the Sacramento River side of the Colusa Basin has levee reaches with design levels of flood protection between 30-year and 40-year recurrence intervals. The 1983 peak flood stages in the Colusa Trough Drainage Canal had estimated recurrence intervals of 40 to 60 years (there were reaches of observable levee distress during the 1983 flood but no levee failures, although emergency repairs were subsequently required as indicated in Table 1). Based on past records, infrequent storm events generally produce high flood stages in the Colusa Trough Drainage Canal at about the same time as high flood stages are occurring in the Sacramento River opposite the Canal. Because of the above, higher levels of flood protection for that area east of the Colusa Trough Drainage Canal probably cannot be achieved by the recommended repairs.

The reconstruction work proposed for the east levee of the Knights Landing Ridge Cut (see Figure 7) would insure that this project levee could safely convey the design conditions. A levee break at either of the repair sites shown would inundate an area confined by project levees on all sides. (See Figure 8.) In the "Mid-Valley Area, Initial Appraisal Report", Corps of Engineers, December 1991, reconstruction work was also recommended for the west levee of the Sacramento River opposite the community of Knights Landing. The estimated existing (without project condition) levels of flood protection for the Knights Landing area were estimated at a 40-year recurrence interval on the Knights Landing Ridge Cut side and a 60-year recurrence interval on the Sacramento River side.

The average annual without project damages for existing conditions, a 21-day duration of flooding, and a 40-year nondamaging level of flood protection is about $530,000 for the Knights Landing area. The combined cost of levee repairs for this area is about $3.7 million (the cost of reconstruction of the west levee of the Sacramento River is about $1.7 million based on the Mid-Valley Area, Initial Appraisal Report, and the cost of reconstruction of the east levee of the Knights Landing Ridge Cut is about $2 million as shown in Table 3). If half the benefits within the freeboard range are attributed to the reconstruction proposed, the benefits exceed the costs (a benefit to cost ratio that could range from 1.1 to

1.5 depending on upstream levee breaching), The cost of doing the combined work could be less than that shown above if only one contract for construction is necessary (combining the reconstruction work will minimize engineering and institutional efforts since only one Project Cooperation Agreement, one set of plans and specifications, and one construction contract would be required for the Knights Landing area).

Based on the economic evaluation (results summarized above), reconstruction work for the levees surrounding the community of Knights Landing is economically justified based on an incremental analysis and assuming that the Mid-Valley Area work is combined with this work as one contract. Reconstruction work for the west levee of the Knights Landing Ridge Cut and the Colusa Trough Drainage Canal is not justified incrementally

Because public safety is a primary concern, there is also potential justification for Federal participation in reconstruction work for the levees around Knights Landing. This potential flood hazard area includes about 500 structures, primarily residences, and about 850 people. A major adverse impact resulting from a levee failure in this area is the potential for loss of human life. Depths of flooding resulting from levee failure could range up to a maximum of 15 feet. Because of the depths of flooding possible and the potential for unexpected levee failures, loss of life could result.

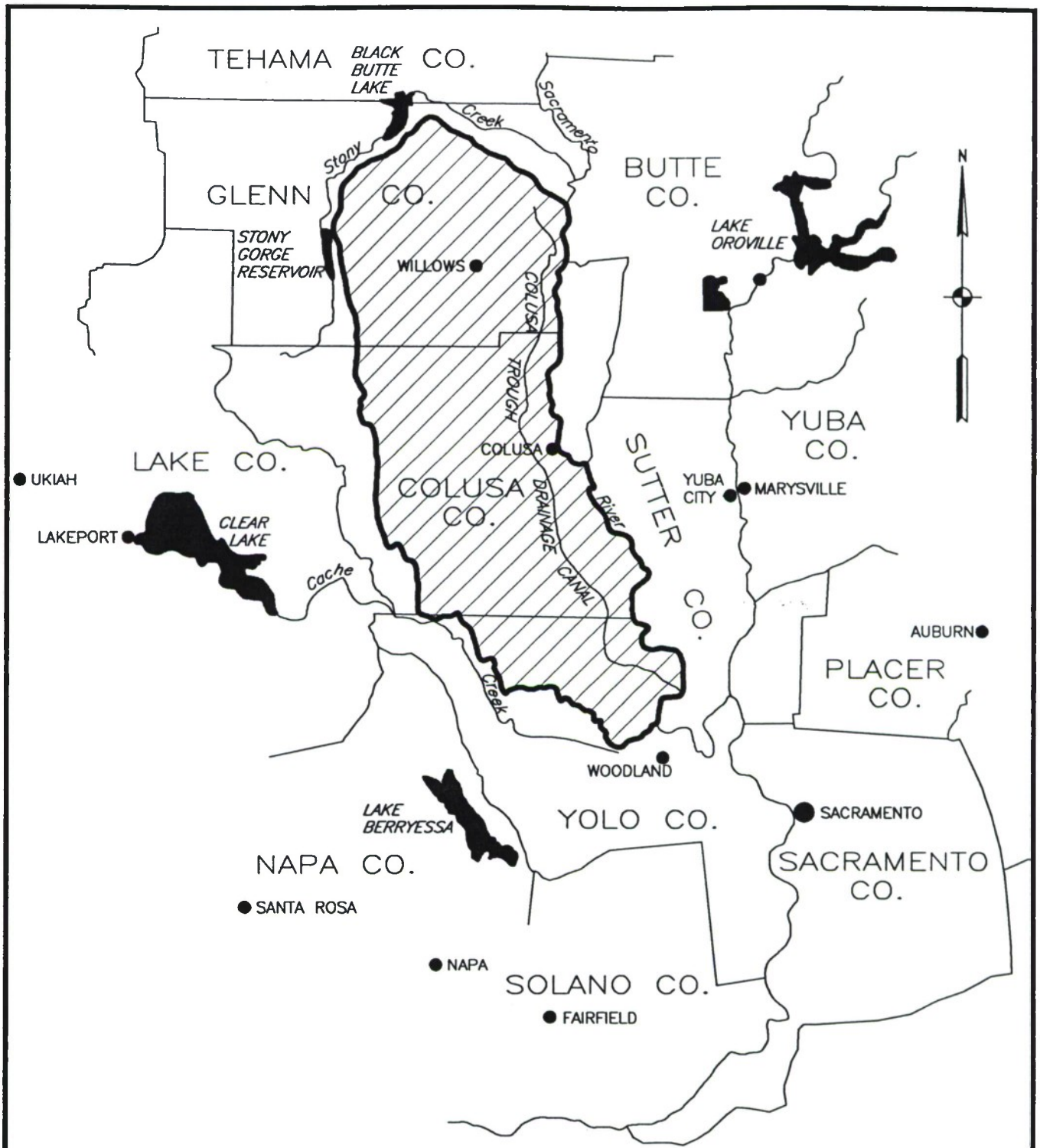
V. CONCLUSIONS

Based on a comparison of with and without project conditions, reconstruction work proposed for the Colusa Trough Drainage Canal levee and the west levee of the Knights Landing Ridge Cut is not economically justified incrementally. Reconstruction work proposed for the east levee of the Knights Landing Ridge Cut is incrementally justified when combined with repairs recommended for the west levee of the Sacramento River (as presented in the "Mid-Valley Area, Initial Appraisal Report", Corps of Engineers, December, 1991) opposite Knights Landing.

Further development of plans for reconstruction of the east levee of Knights Landing Ridge Cut will be accomplished in conjunction with the Mid-Valley Area design effort. The construction of all work proposed around an independent flood hazard area as one unit will insure that the design level of flood protection for that area, which includes the community of Knights Landing, will be met at one point in time. Geotechnical and design information developed under the Colusa Trough Drainage Canal investigation can easily be incorporated in the Mid-Valley Area design memorandum. In addition, this will minimize engineering and institutional efforts because only one Project Cooperation Agreement, one set of plans and specifications, and one construction contract would be required for the Knights Landing area.

Reconstruction work which has been shown to be incrementally infeasible in this investigation will be considered in other phases of the Sacramento River Flood Control System Evaluation. That work proposed for the Colusa Trough Drainage Canal levee (which is incrementally infeasible) will be considered along with the west levee of the Sacramento River opposite the canal. These two levees provide flood protection for the same potential flood hazard area and, as such, it would be appropriate to

evaluate these levees concurrently. Based on the above, repair work for the Colusa Trough Drainage Canal levee will be addressed in the Initial Appraisal Report for the Upper Sacramento Area, Phase V, of the Sacramento River Flood Control System Evaluation. This same reasoning also applies to work proposed for the west levee of the Knights Landing Ridge Cut (which is also incrementally infeasible). This work will be addressed in the Initial Appraisal Report for Lower Sacramento Area, Phase IV, of the Sacramento River Flood Control System Evaluation.

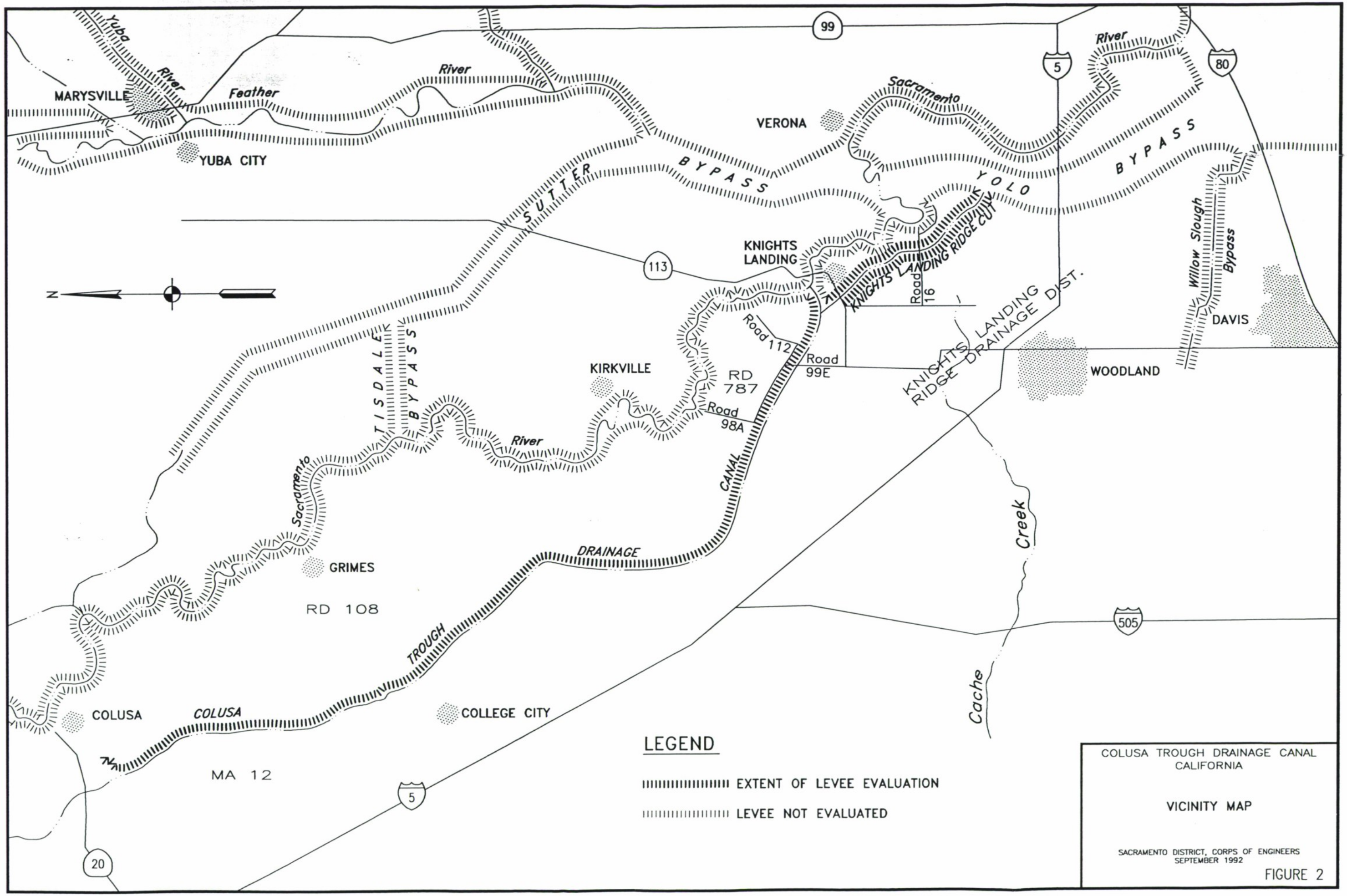


COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

LOCATION MAP
COLUSA BASIN

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 1

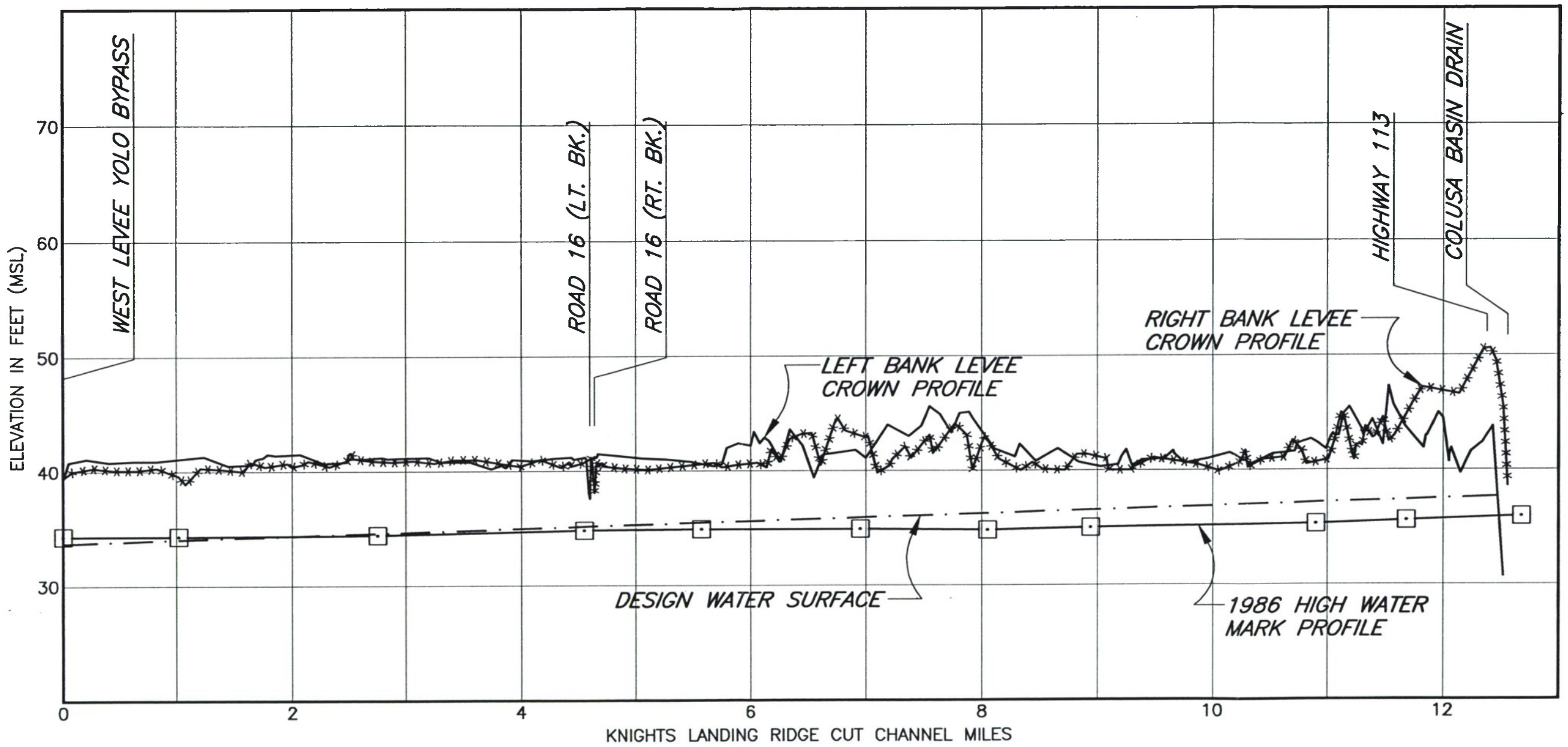


COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

VICINITY MAP

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 2

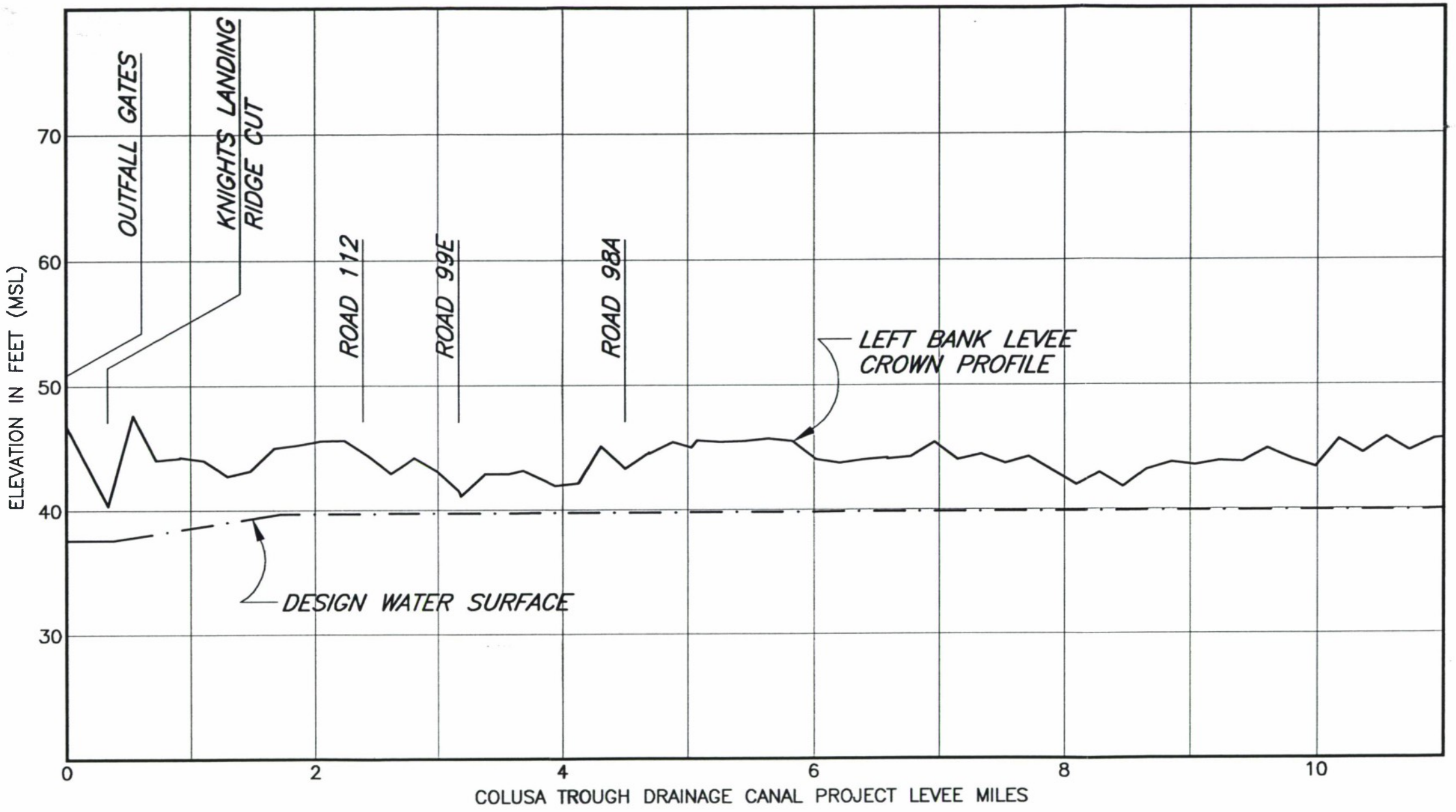


COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

LEVEE CROWN AND WATER SURFACE PROFILES KNIGHTS LANDING RIDGE CUT

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 3

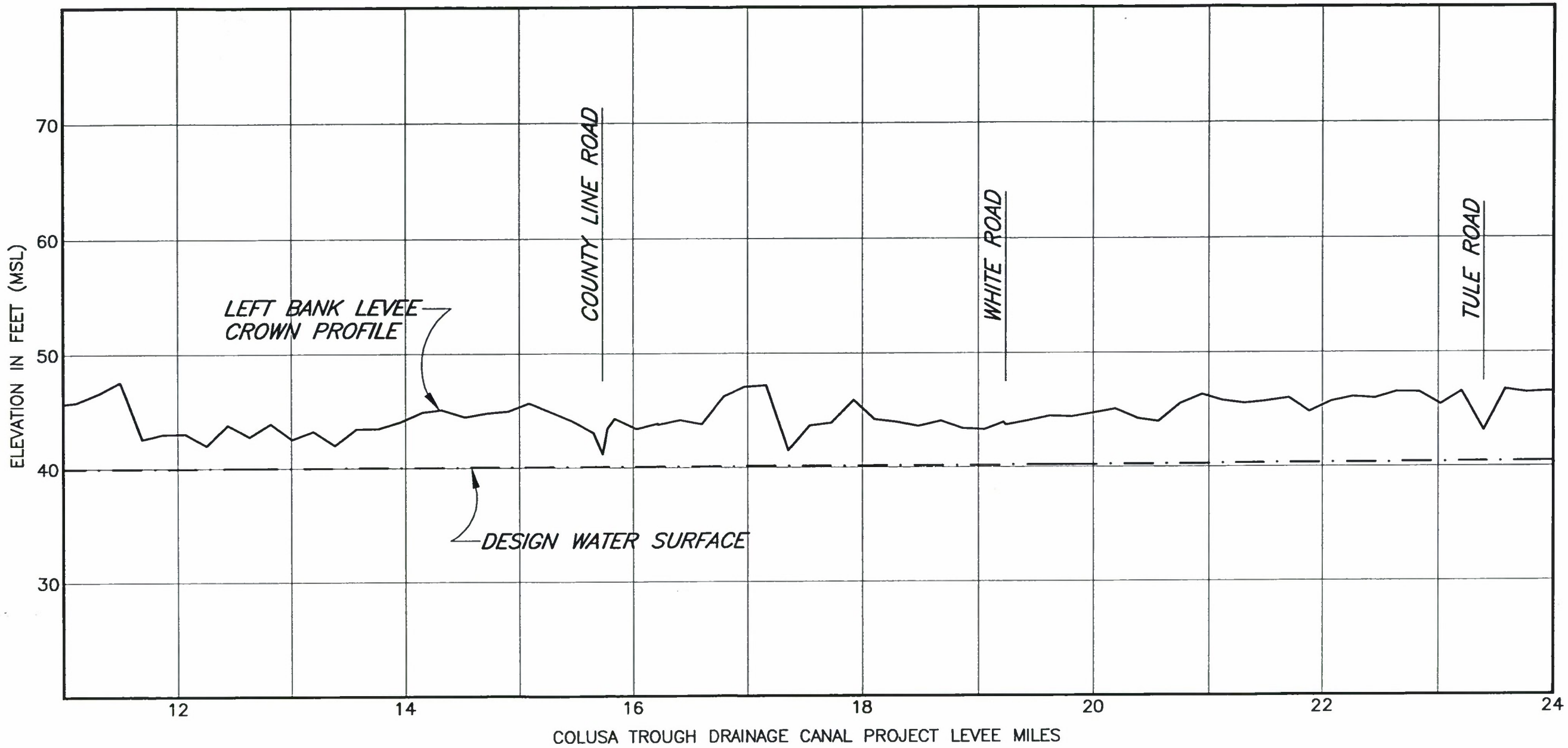


COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

LEVEE CROWN AND WATER SURFACE PROFILES COLUSA TROUGH DRAIN

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 4

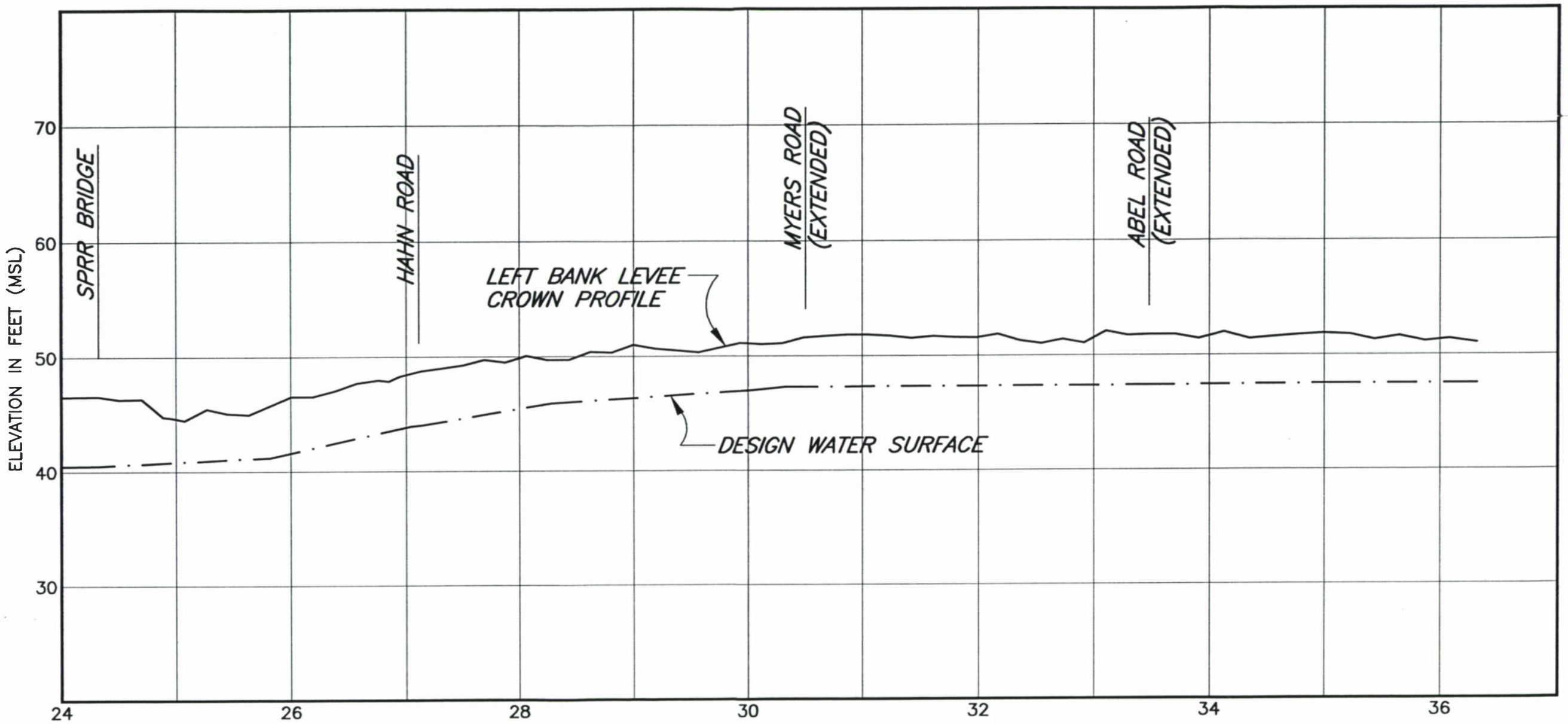


COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

**LEVEE CROWN AND
WATER SURFACE PROFILES
COLUSA TROUGH DRAIN**

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 5

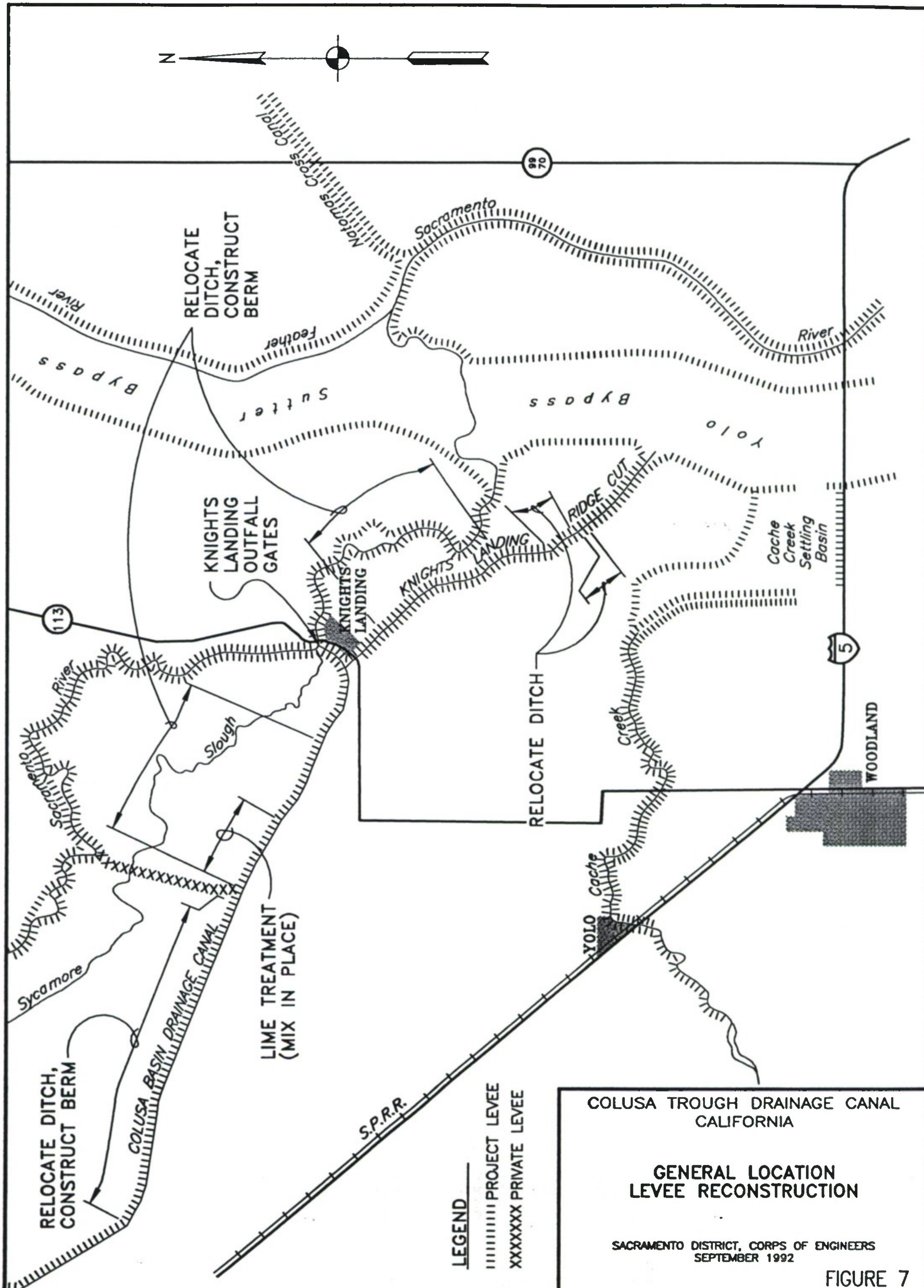


COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

LEVEE CROWN AND WATER SURFACE PROFILES COLUSA TROUGH DRAIN

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 6

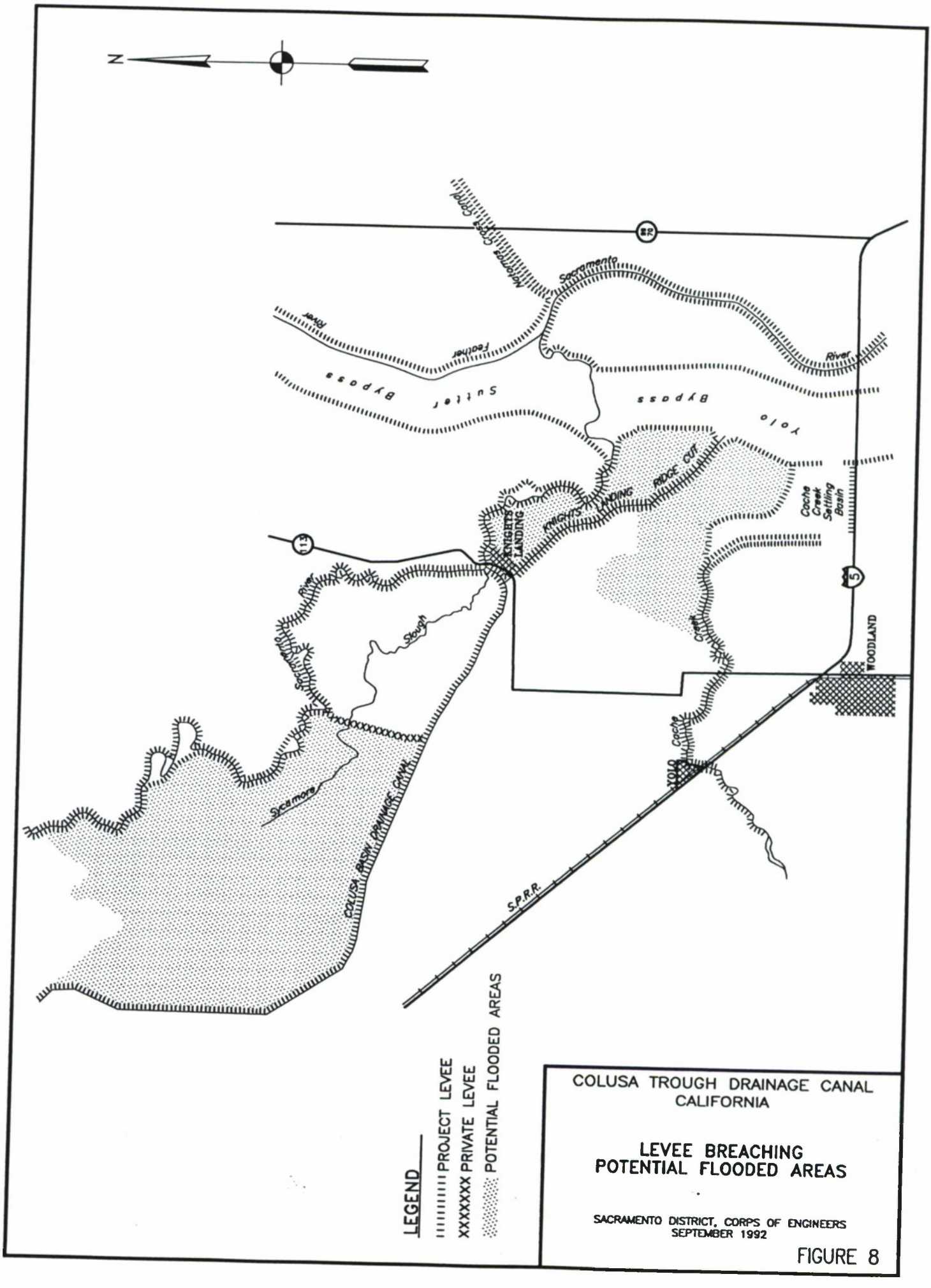


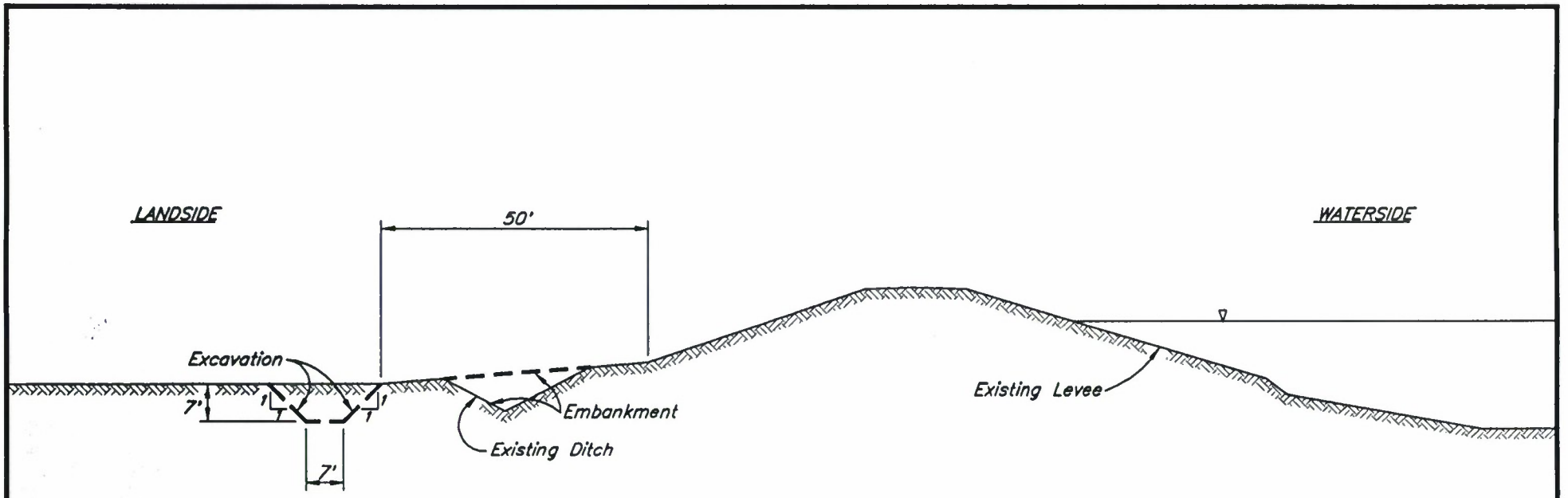
COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

GENERAL LOCATION
LEVEE RECONSTRUCTION

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 7


N
22
Sacramento River
Feather River
Sutter Bypass
Bypass
River
Yolo
Ridge Cut
Knights Landing
KNIGHTS LANDING
Cache Creek Settling Basin
113
5
Slough
Sycamore
Creek
WOODLAND
Cache
COLUSA BASIN DRAINAGE CANAL
S.P.R.R.
LEGEND
PROJECT LEVEE
XXXXXXX PRIVATE LEVEE
POTENTIAL FLOODED AREAS
COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA
LEVEE BREACHING
POTENTIAL FLOODED AREAS
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992
FIGURE 8



LANDSIDE DITCH RELOCATION

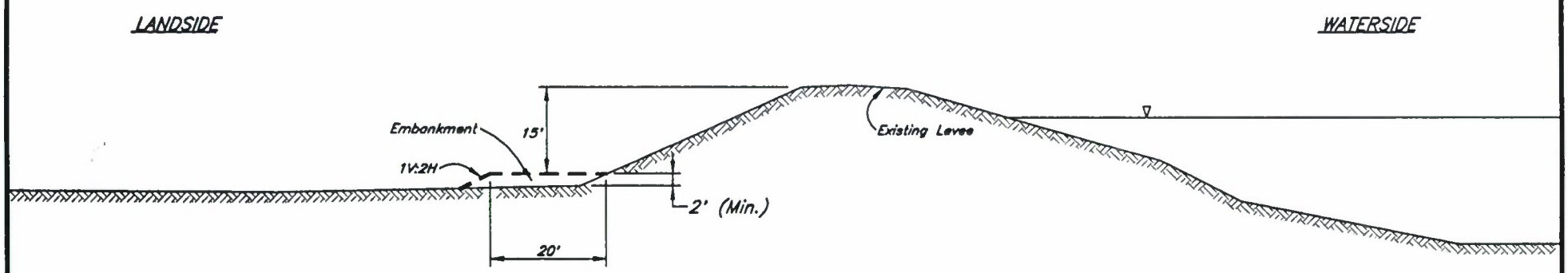
NOTE: Dimensions shown can vary depending on site-specific conditions.

COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

RECONSTRUCTION DESIGN
LANDSIDE DITCH RELOCATION

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 9



LANDSIDE BERM CONSTRUCTION

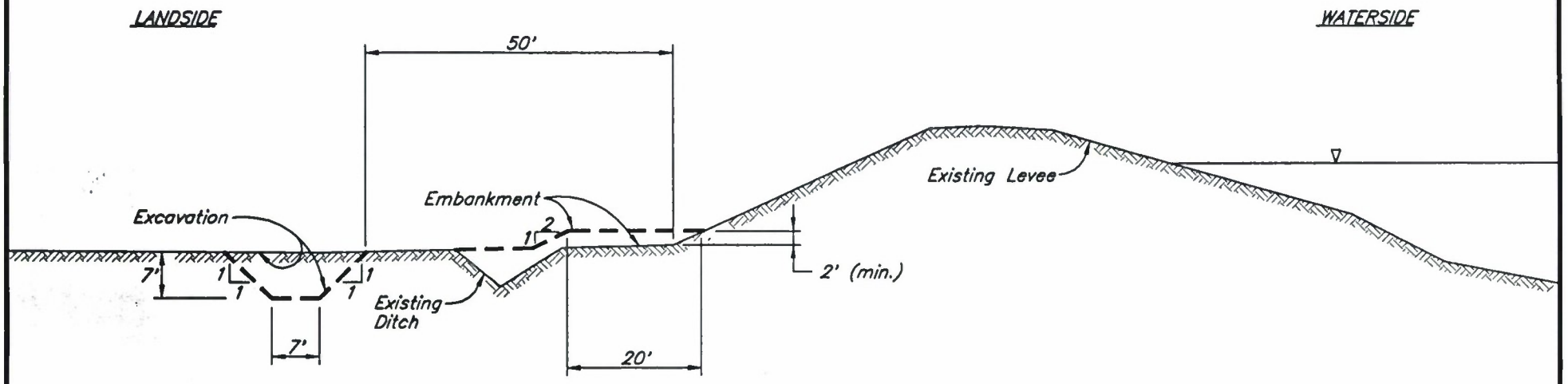
NOTE: *Dimensions shown can vary depending on site-specific conditions.*

COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

RECONSTRUCTION DESIGN
LANDSIDE BERM
CONSTRUCTION

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 10



LANDSIDE BERM CONSTRUCTION AND DITCH RELOCATION

NOTE: *Dimensions shown can vary depending on site-specific conditions.*

COLUSA TROUGH DRAINAGE CANAL
CALIFORNIA

RECONSTRUCTION DESIGN
LANDSIDE BERM CONSTRUCTION
AND DITCH RELOCATION

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SEPTEMBER 1992

FIGURE 11

TO: Defense Technical Information Center
ATTN: DTIC-O
8725 John J. Kingman Road, Suite 0944
Fort Belvoir VA 22060-6218

22 October 2008

FROM: US Army Corps of Engineers
Sacramento District Library
1325 J Street, Suite 820
Sacramento CA 95814-2292

SUBJECT: Submission of technical reports for inclusion in Technical Reports Database

The enclosed documents from USACE Sacramento District are hereby submitted for inclusion in DTIC's technical reports database. The following is a list of documents included in this shipment:

ADB344304 • Lemon Reservoir Florida River, Colorado. Report on reservoir regulation for flood control, July 1974

ADB344333 • Reconnaissance report Sacramento Metropolitan Area, California, February 1989

ADB344346 • New Hogan Dam and Lake, Calaveras River, California. Water Control Manual Appendix III to Master Water Control Manual San Joaquin River Basin, California, July 1983

ADB344307 • Special Flood Hazard Study Nephi, Utah, November 1998 (cataloged)

ADB344344 • Special Study on the Lower American River, California, Prepared for US Bureau of Reclamation – Mid Pacific Region and California Dept. of Water Resources..., March 1987

ADB344313 • Transcript of public meeting Caliente Creek stream group investigation, California, held by, the Kern County Water Agency in Lamont, California, 9 July 1979

ADB344302 • Initial appraisal Sacramento River Flood control project (Glenn-Colusa), California, 10 February 1989

ADB344485 • Report on November-December 1950 floods Sacramento-San Joaquin river basins, California and Truckee, Carson, and Walker rivers, California and Nevada, March 1951

ADB344268 • Reexamination Little Dell Lake, Utah, February 1984

ADB344197 • Special report fish and wildlife plan Sacramento River bank protection project, California, first phase, July 1979

ADB344264 • Programmatic environmental impact statement/environmental impact report Sacramento River flood control system evaluation, phases II-V, May 1992

ADB344201 • Hydrology office report Kern river, California, January 1979

ADB344198 • Kern River – California aqueduct intertie, Kern county, California, environmental statement, February 1974

ADB344213 • Sacramento river Chico Landing to Red Bluff, California, bank protection project, final environmental statement, January 1975

ADB344265 • Cottonwood Creek, California, Information brochure on selected project plan, June 1982

ADB344261 • Sacramento river flood control project Colusa Trough Drainage Canal, California, office report, March 1993

ADB344343 • Detailed project report on Kern River-California aqueduct intertie, Kern County, California. February 1974

ADB344267 • Sacramento River Flood Control Project, California, Right Bank Yolo Bypass and Left Bank Cache Slough near Junction Yolo Bypass and Cache Slough, Levee construction, General Design, Supplement No. 1 to Design Memorandum #13, May 1986

ADB344246 • Redbank and Fancher Creeks, California, General Design Memorandum #1, February 1986

ADB344260 • Cache Creek Basin, California, Feasibility report and environmental statement for water resources development Lake and Yolo counties, California, February 1979

ADB344199 • Sacramento River Deep Water Ship channel, California, Feasibility report and environmental impact statement for navigation and related purposes, July 1980

ADB344263 • Sacramento River flood control project, California, Mid-Valley area, phase III, Design Memorandum, Vol. I or II, June 1986

ADB344262 • Marysville Lake, Yuba River, California, General Design Memorandum Phase I, Plan Formulation, Preliminary Report, Appendixes A-N, Design Memorandum #3, March 1977

The **distribution statement is A** approved for public release; distribution is unlimited.

The Sacramento District source code is **410637**. Please return any materials that aren't appropriate for the technical reports database.

Please acknowledge receipt of shipment by sending email message to Frances.J.Sweeney@usace.army.mil.

Thank you,

Frances J. Sweeney
Library Manager
USACE, Sacramento District Library
916-557-6660